US 20160159232A1

(19) United States

(12) Patent Application Publication

WEIGEL et al.

(10) Pub. No.: US 2016/0159232 A1

(43) Pub. Date: Jun. 9, 2016

(54) **CONTACT APPARATUS AND CHARGING CONTACT UNIT AND METHOD FOR ELECTRICALLY CONNECTING A VEHICLE TO A CHARGING STATION**

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(21) Appl. No.: **14/908,676**

(22) PCT Filed: **Aug. 7, 2014**

(86) PCT No.: **PCT/US2014/066983**

§ 371 (c)(1),
(2) Date: **Jan. 29, 2016**

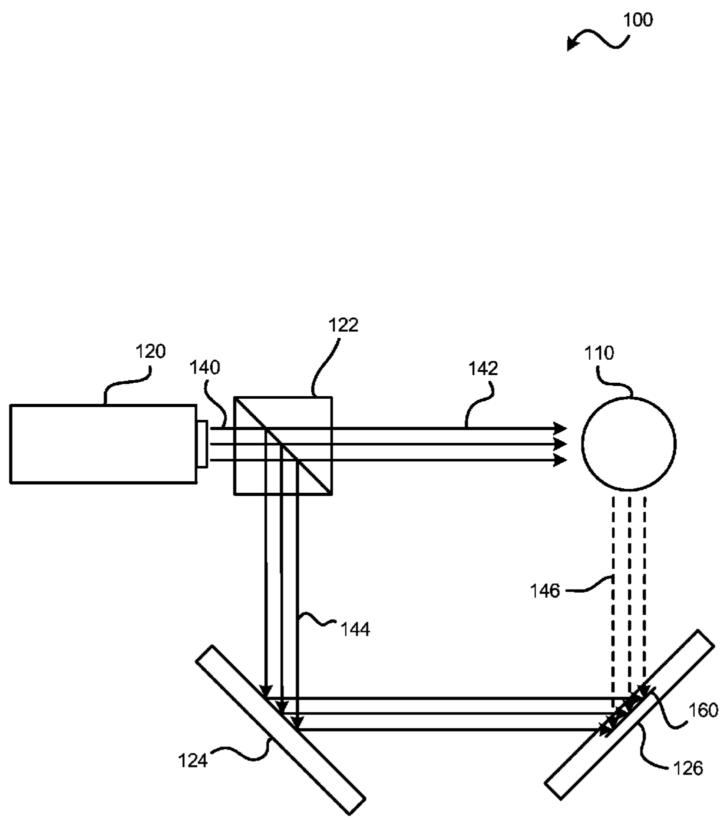
**Publication Classification**

(51) **Int. Cl.**
***B60L 11/18*** (2006.01)

(52) **U.S. Cl.**
CPC ......... ***B60L 11/1818*** (2013.01); ***B60L 11/1827*** (2013.01); ***B60L 11/1838*** (2013.01)

(57) **ABSTRACT**

The invention relates to a contact apparatus (**11**) and to a charging contact unit (**12**) for a rapid-charging system for electrically driven vehicles, in particular electric buses or the like, and to a method for forming an electrically conductive connection between a vehicle and a stationary charging station, wherein the contact apparatus serves to form an electrically conductive connection between the vehicle and the stationary charging station comprising a charging contact unit, wherein the contact apparatus can be arranged on a vehicle, wherein the contact apparatus comprises a contact device (**14**), wherein the contact device can make contact with the charging contact unit, wherein the contact apparatus or the charging contact unit comprises a positioning device (**15**), wherein the contact device can be positioned relative to the charging contact unit by means of the positioning device, wherein the positioning device has a pantograph or a swing arm (**19**), by means of which the contact device can be positioned in the vertical direction relative to the charging contact unit, wherein the contact device has a contact element support comprising contact elements (**17**), wherein the contact elements can make contact with the charging contact elements of the charging contact unit so as to form contact pairs, wherein the positioning device has a transverse guide (**25**), by means of which the contact element support can be positioned transversely relative to the charging contact unit, wherein the transverse guide is arranged at a distal end of the pantograph or of the swing arm (**19**).



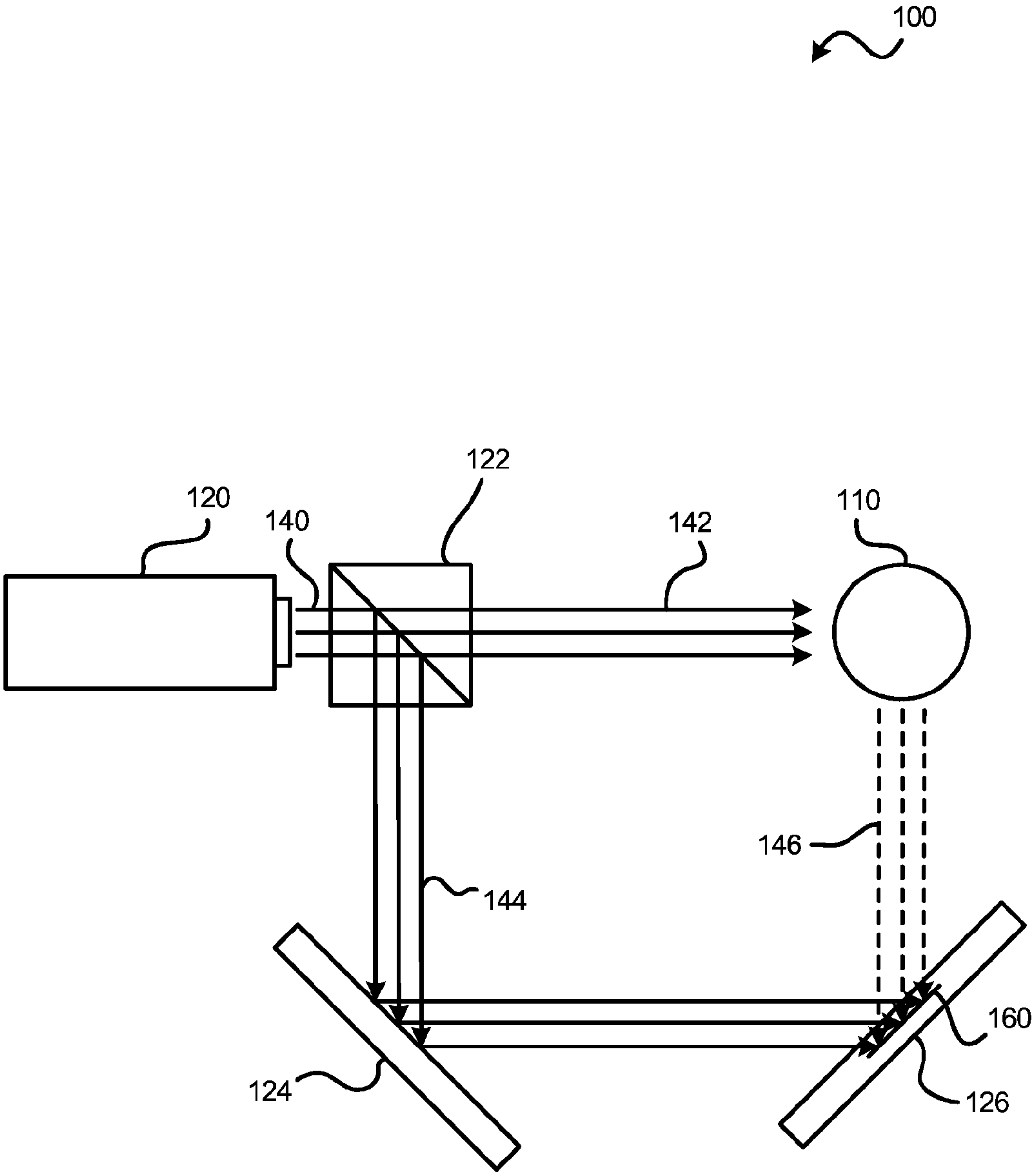



FIG. 1

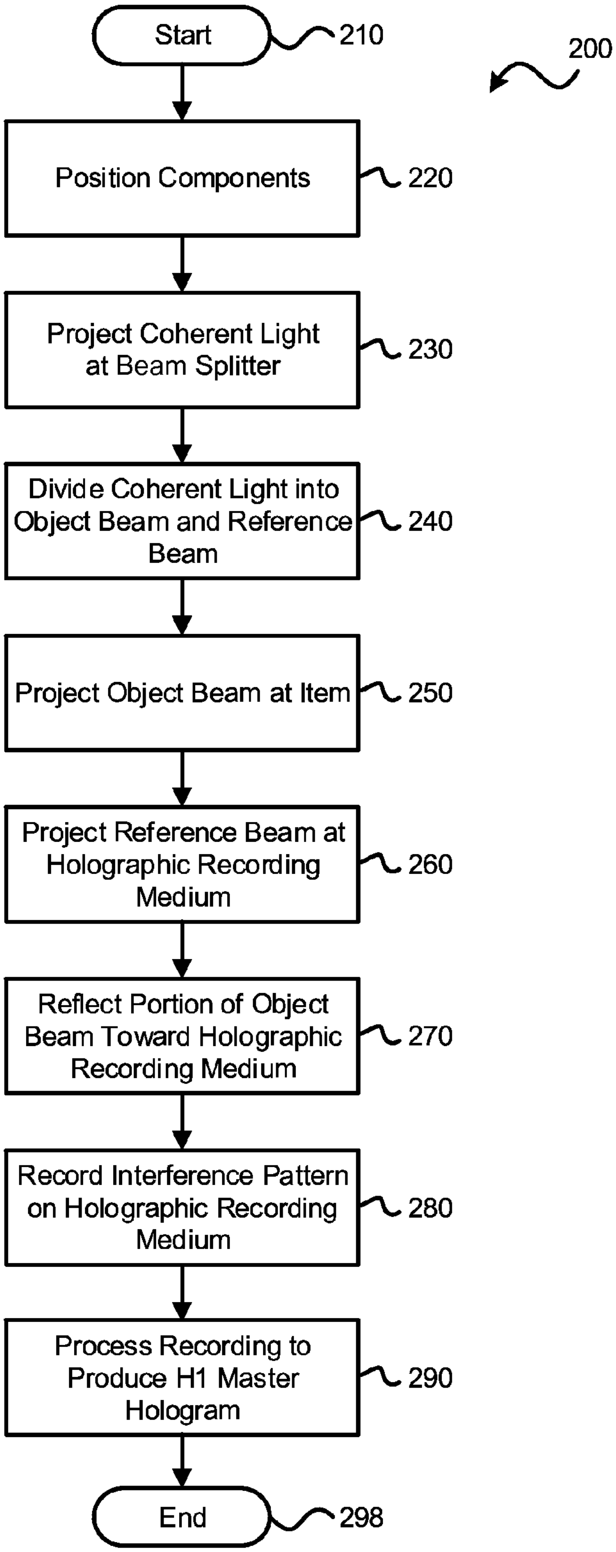

Start
210
200
Position Components
220
Project Coherent Light at Beam Splitter
230
Divide Coherent Light into Object Beam and Reference Beam
240
Project Object Beam at Item
250
Project Reference Beam at Holographic Recording Medium
260
Reflect Portion of Object Beam Toward Holographic Recording Medium
270
Record Interference Pattern on Holographic Recording Medium
280
Process Recording to Produce H1 Master Hologram
290
End
298

*FIG. 2*

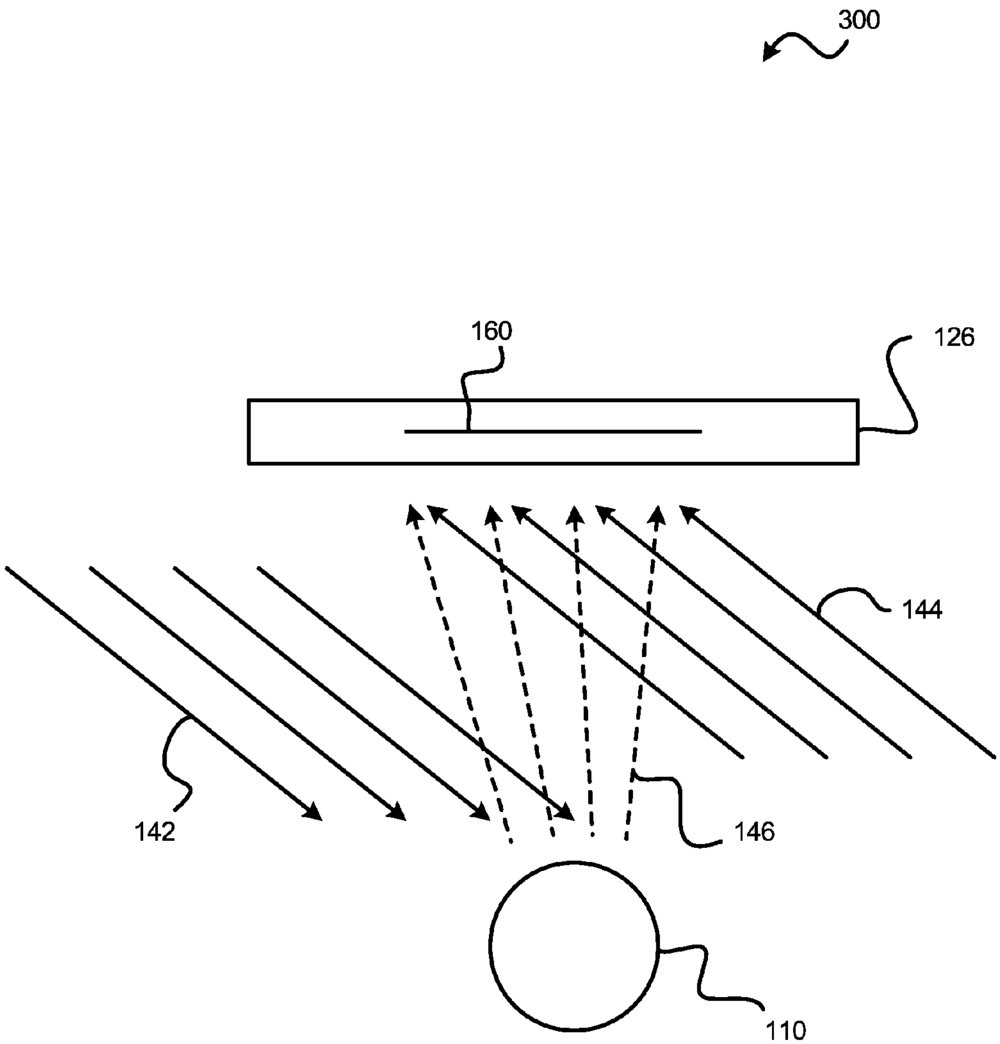



*FIG. 3*

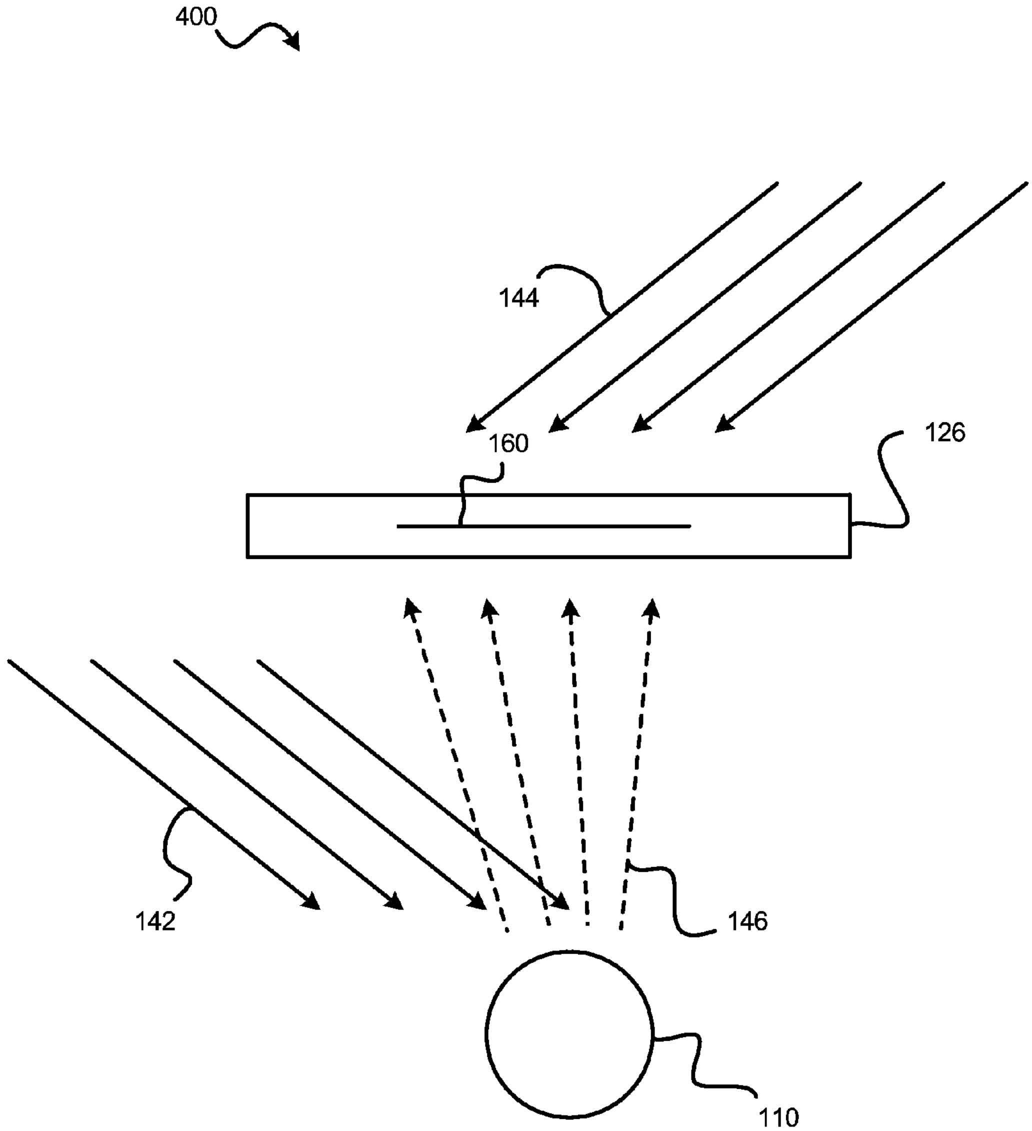



FIG. 4

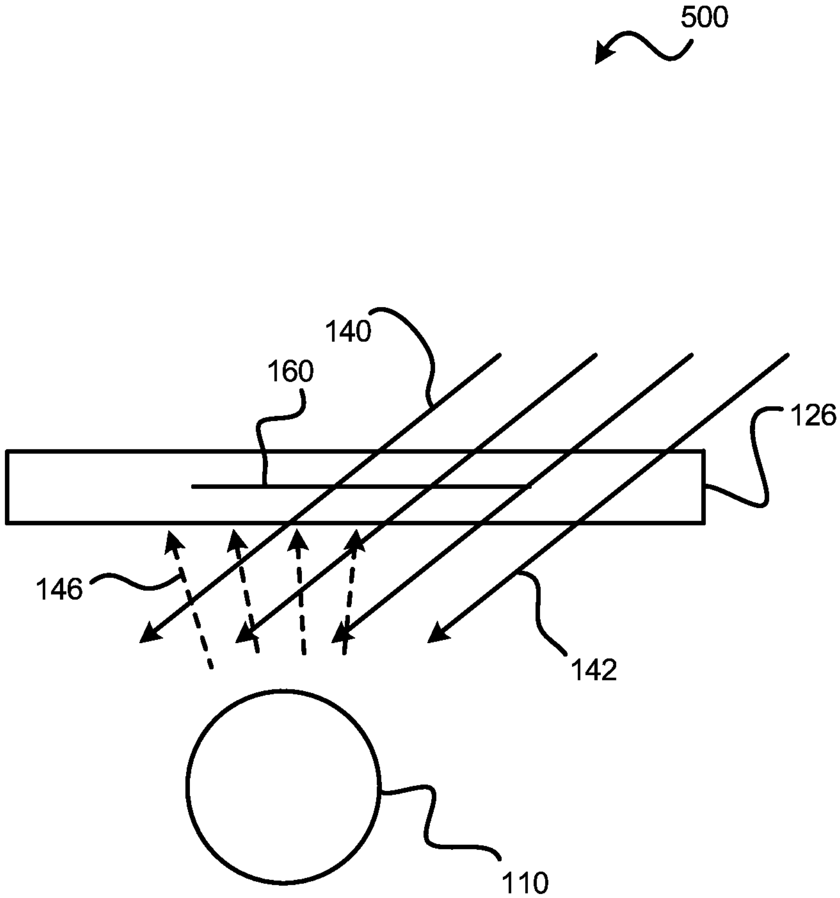



*FIG. 5*

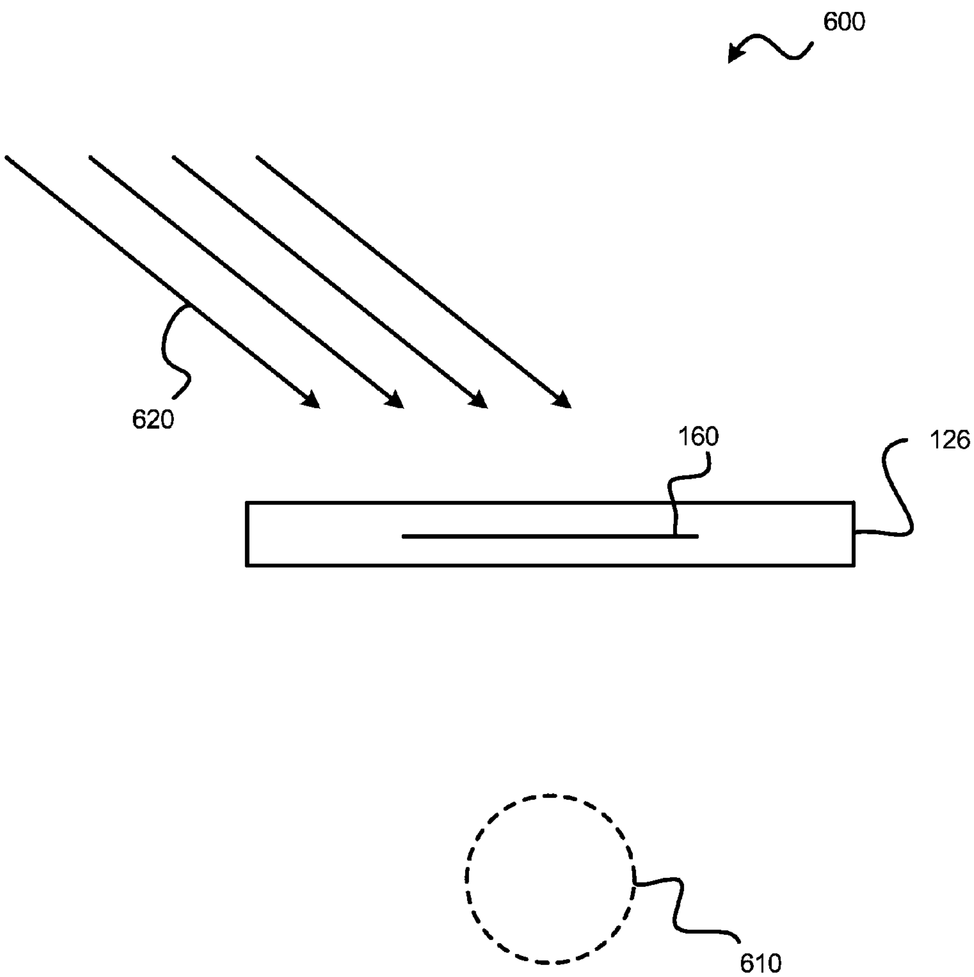



*FIG. 6*

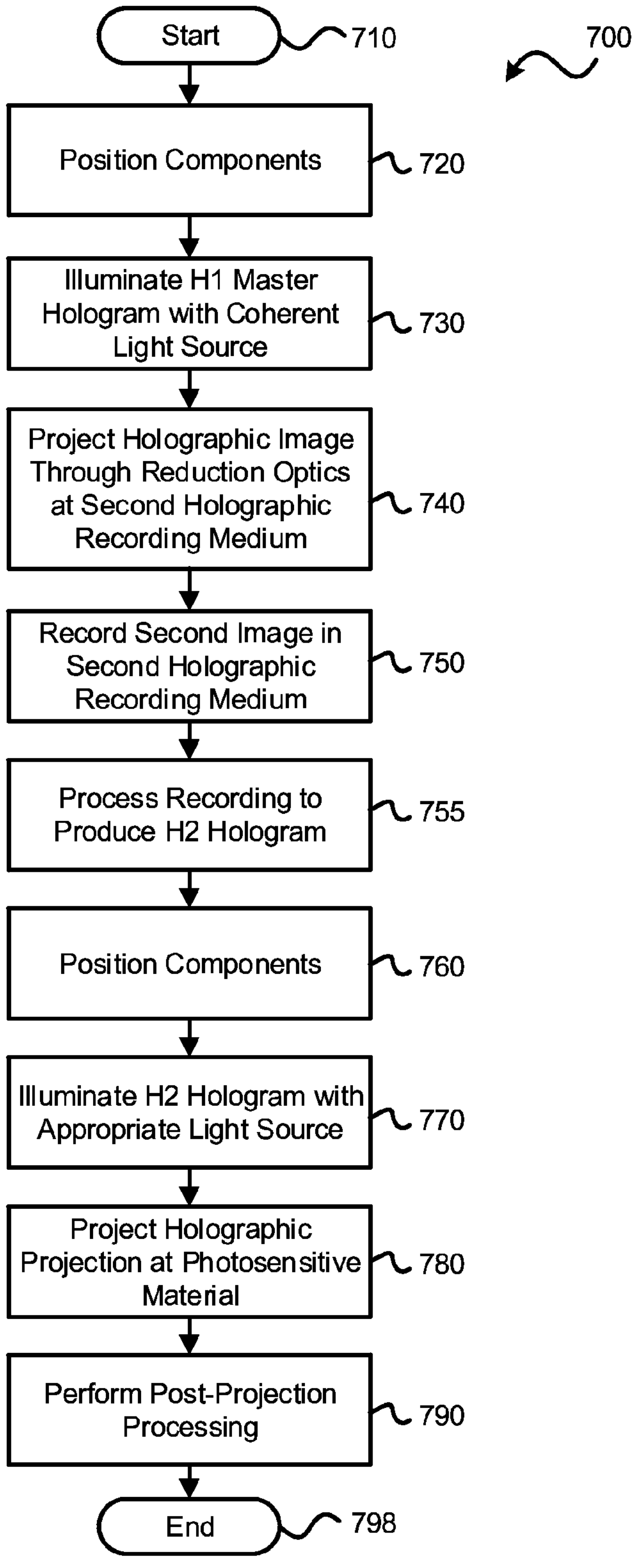

Start
710
700
Position Components
720
Illuminate H1 Master Hologram with Coherent Light Source
730
Project Holographic Image Through Reduction Optics at Second Holographic Recording Medium
740
Record Second Image in Second Holographic Recording Medium
750
Process Recording to Produce H2 Hologram
755
Position Components
760
Illuminate H2 Hologram with Appropriate Light Source
770
Project Holographic Projection at Photosensitive Material
780
Perform Post-Projection Processing
790
End
798

FIG. 7

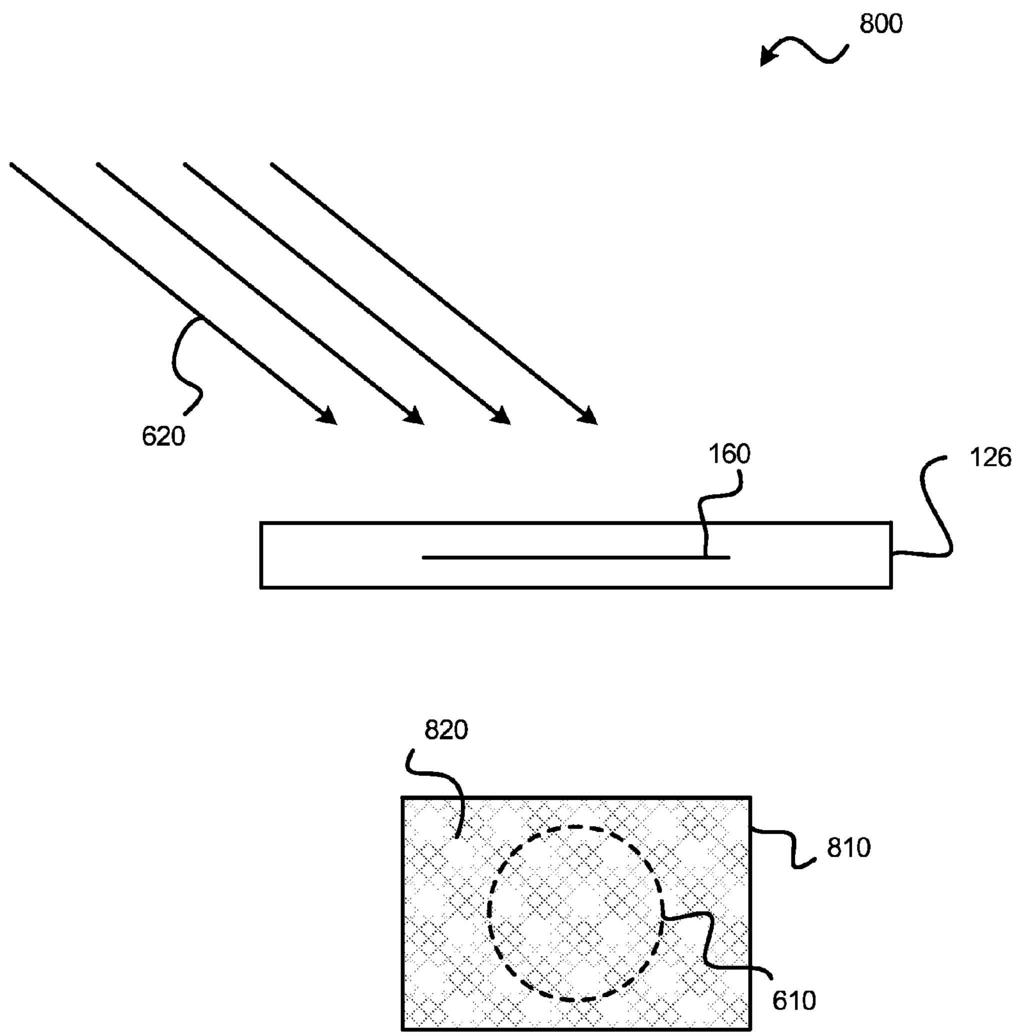



*FIG. 8*

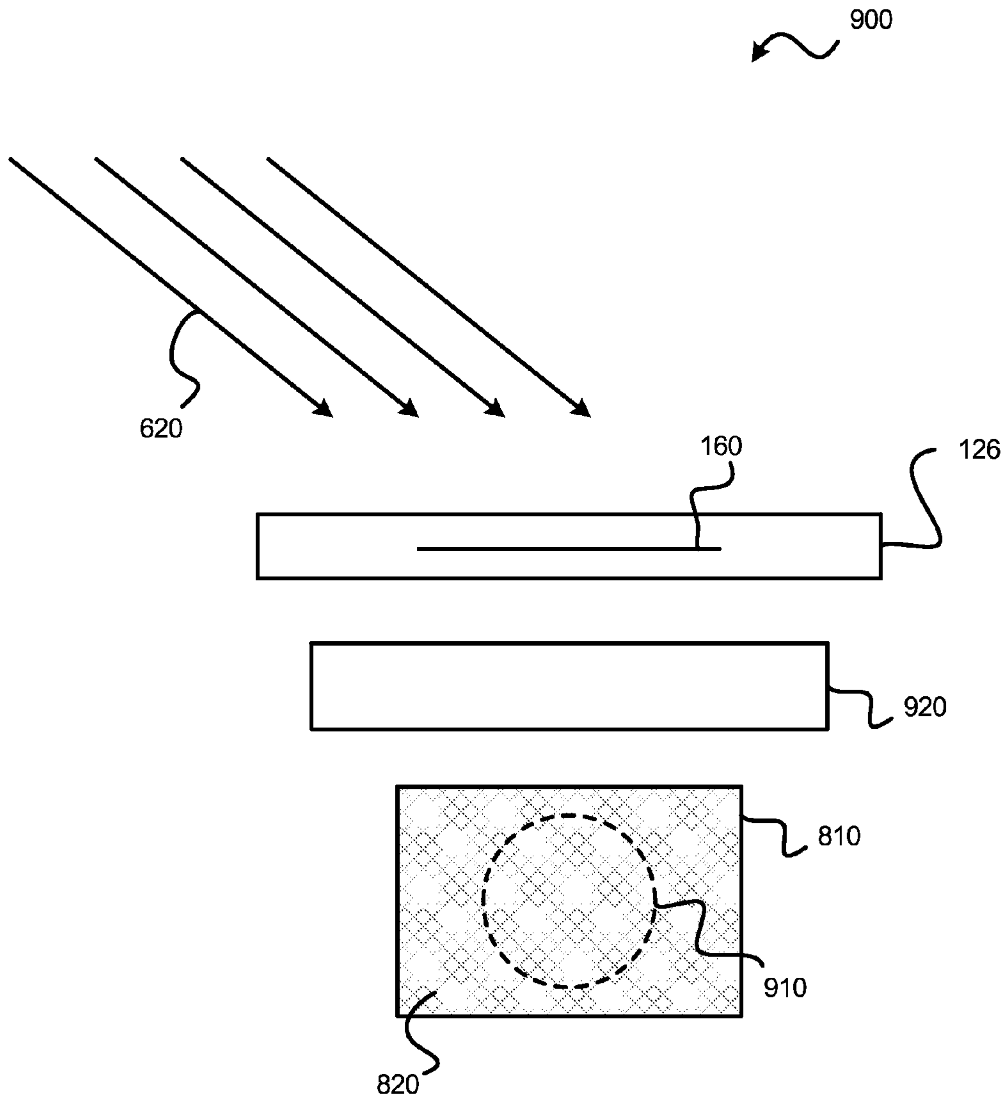



FIG. 9

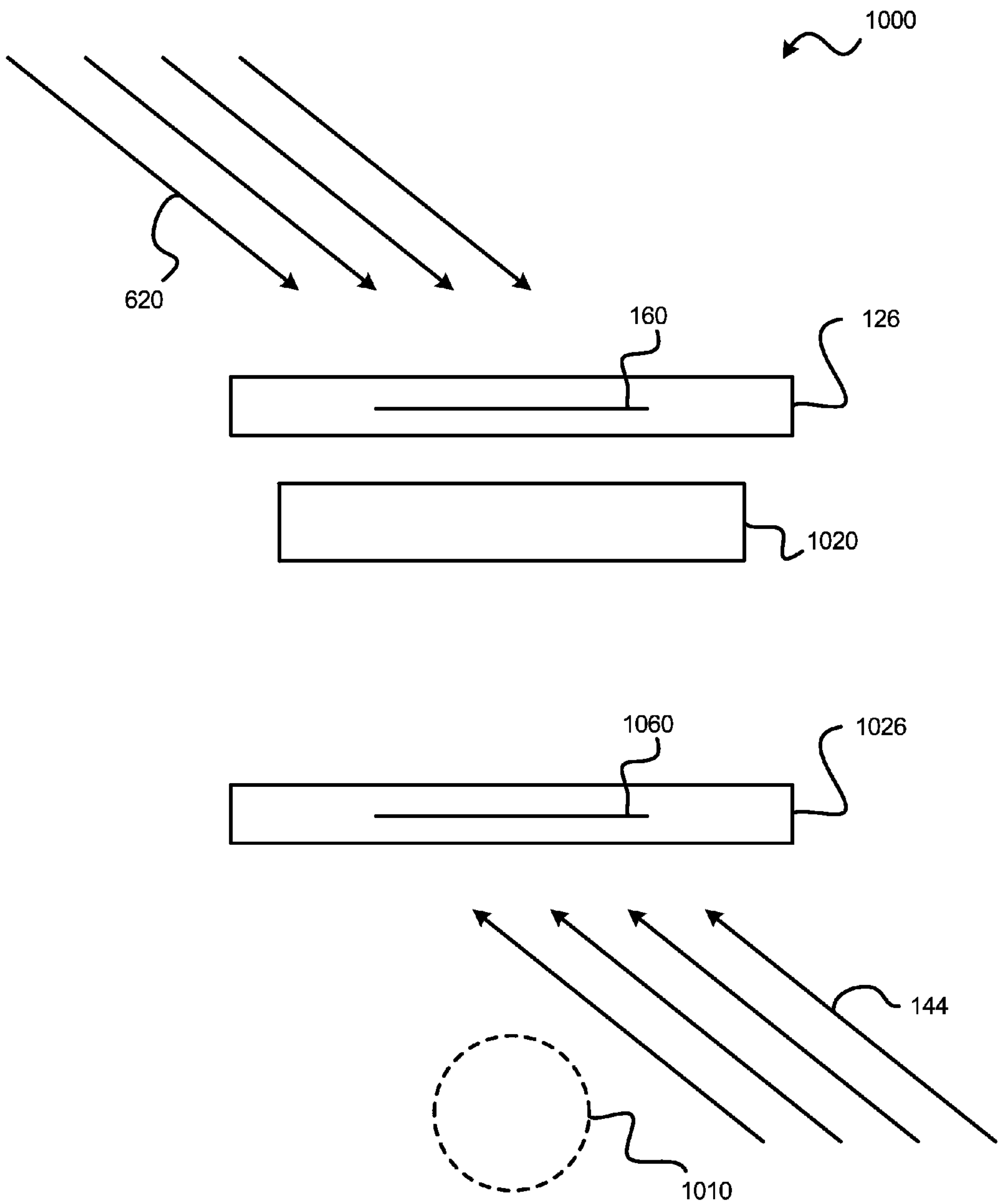



*FIG. 10*

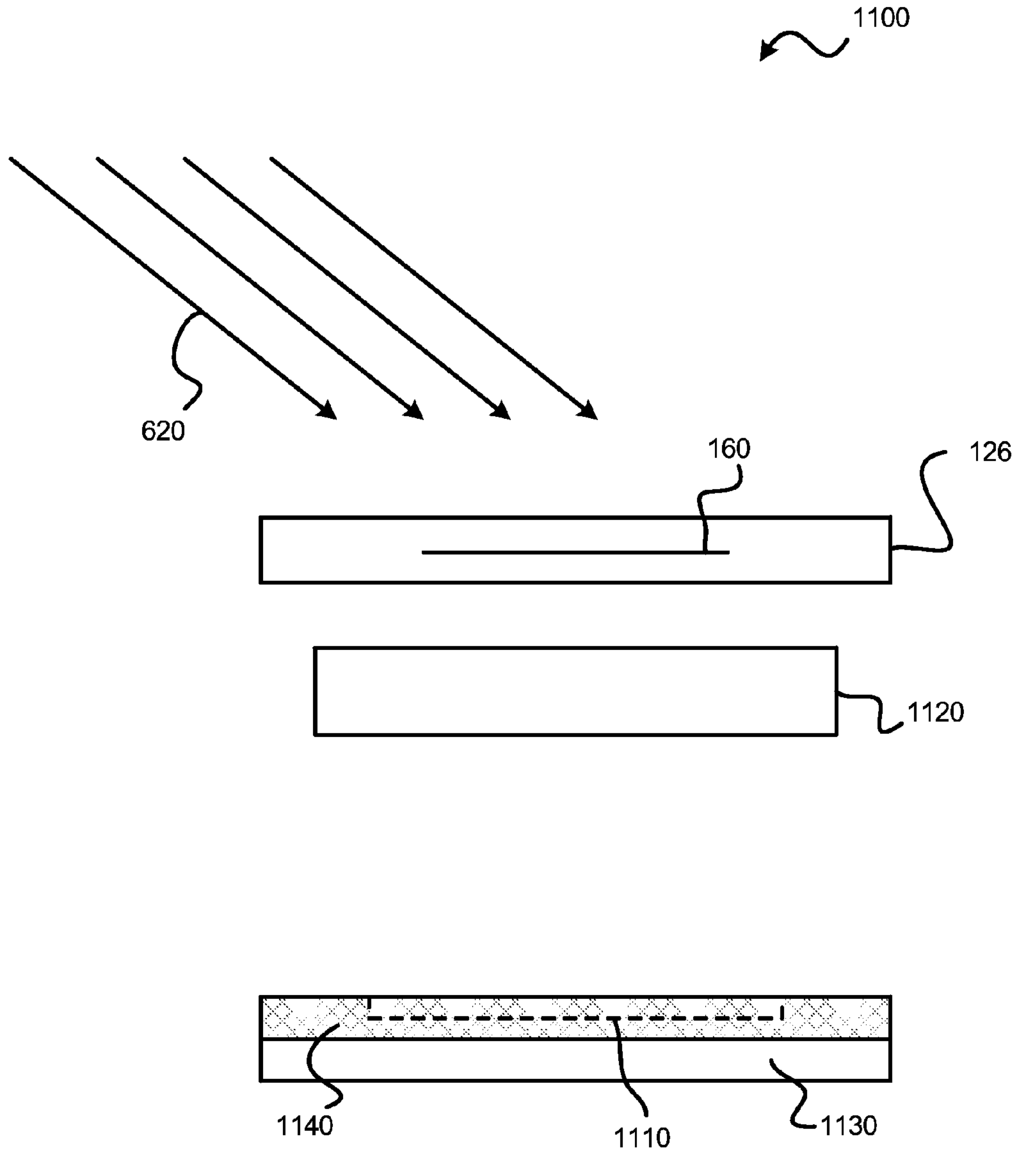



*FIG. 11*

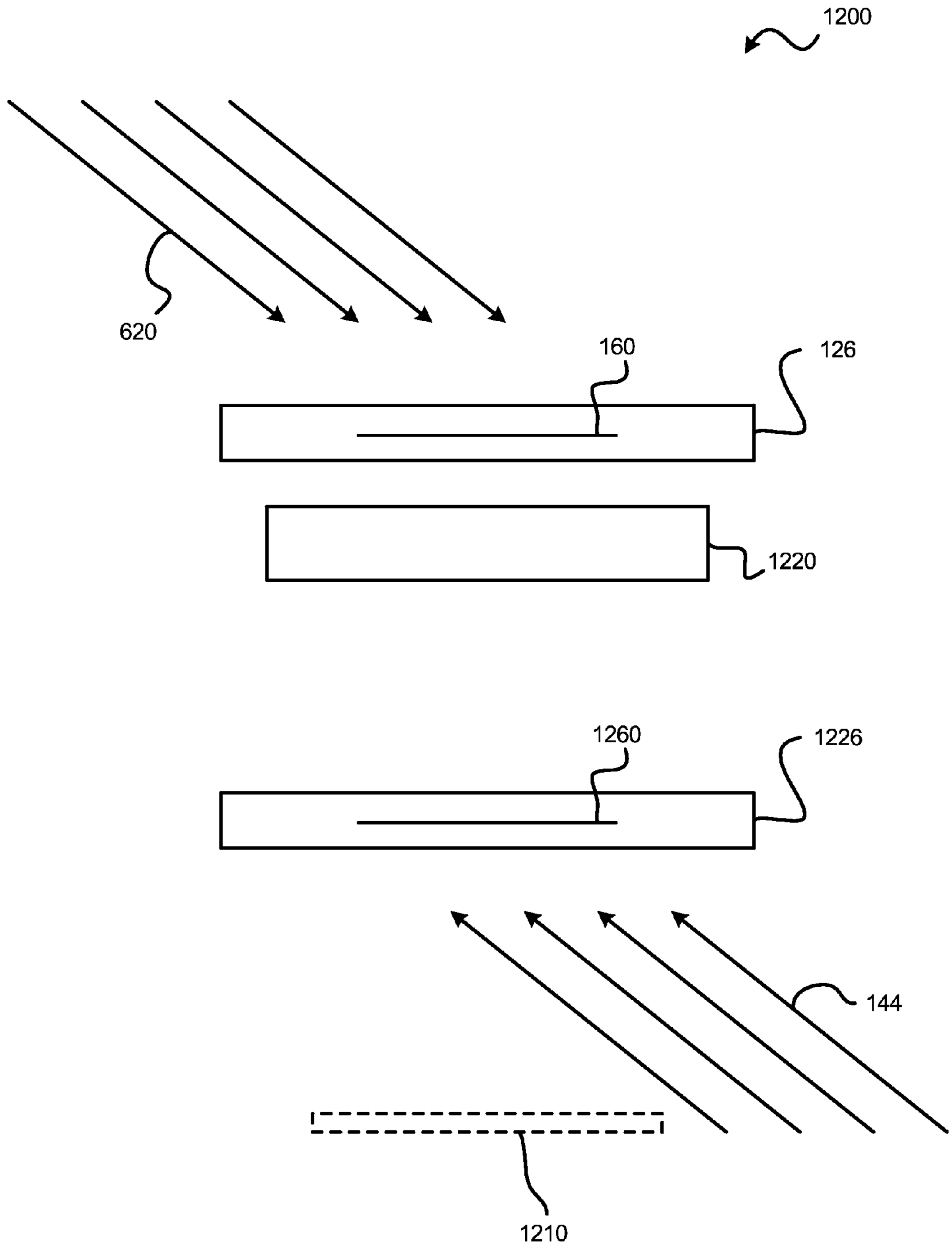



FIG. 12

# CONTACT APPARATUS AND CHARGING CONTACT UNIT AND METHOD FOR ELECTRICALLY CONNECTING A VEHICLE TO A CHARGING STATION

## TECHNICAL FIELD

**[0001]** The present invention relates to fabrication of items, and more particularly, to systems and method of using holography to facilitate optical manufacturing processes.

## BACKGROUND

**[0002]** In many manufacturing processes, electromagnetic energy is used to selectively process materials. Electromagnetic energy includes a spectrum of wavelengths including visible light, higher-frequency energy (such as ultraviolet light, X-rays, and Gamma rays), and lower-frequency energy (such as radio waves, microwaves, and infrared radiation). For simplicity, electromagnetic energy of all wavelengths is often referred to as "light." Materials that undergo a significant change in response to impingement of light are called "photosensitive materials."

**[0003]** Existing light-based manufacturing processes include 3D printing, photolithography, and a variety of other processes. These processes are limited in many respects. Many such processes are unable to satisfactorily to produce nanostructures, which may be structures that are smaller than 100 nm. There are many reasons for this, including the quality of the reduction optics used to reduce the size of the illuminated image used for fabrication. Even with high-quality reduction optics, diffraction limitations are still present with many manufacturing methods, and limit the amount of image reduction that can be successfully be carried out. Existing interference lithography techniques may be able to create smaller structures than other techniques, but may be limited to production of periodic patterns.

**[0004]** In order to create smaller structures such as MEMS (micro-electromechanical systems) devices and high-density integrated circuits, it would be advantageous to provide fabrication systems or methods that overcome the limitations set forth above.

## SUMMARY

**[0005]** The present invention may remedy the shortcomings of prior art fabrication methods by providing systems and/or methods for holography-based fabrication. Such fabrication may include, but is not limited to, 3D printing and lithography. Such a system may include a coherent light source, a non-coherent narrow line width source, a monochromatic light source, a hologram, a holographic recording medium, and/or a target such as a reservoir of photosensitive material or a photosensitive material attached to a substrate.

**[0006]** A hologram of an original object or a lithographic pattern may be recorded on the holographic recording medium through the use of a variety of techniques including but not limited to transmission holography, reflection holography, and Denisyuk holography. All three methods may involve splitting a beam of coherent light from a coherent light source, such as a laser, into two or more beams. The beams may include an object beam that is used to illuminate the original object or lithographic pattern, and a reference beam that illuminates the holographic recording medium. A portion of the object beam may reflect from the original object or lithographic pattern onto the holographic recording medium. The reflected portion of the object beam may cooperate with the reference beam to define an interference pattern that records a hologram of the original object or lithographic pattern in the holographic recording medium. After processing the holographic recording medium, creation of the hologram may be complete. The hologram may then be used in the described process.

**[0007]** In transmission holography, the reference beam and the reflected portion of the object beam may both impinge against the same side of the holographic recording medium. In reflection holography, the reference beam and the reflected portion of the object beam may impinge against opposite sides of the holographic recording medium. In Denisyuk holography, the holographic recording medium may, itself, be used as a beam splitter that divides the coherent light into the object beam and the reference beam.

**[0008]** Once the hologram has been recorded and processed, it may be considered an "H1 master hologram" that may be used to fabricate objects and/or create one or more derivative holograms. Specifically, a light source, of a desired wavelength, may be directed at the H1 master hologram to form a holographic image of the original object or lithographic pattern. The holographic image may be positioned in a reservoir of photosensitive material, on a photosensitive material attached to a substrate for lithographic processing, or the like. This may result in the formation of a new object from the photosensitive material, or may facilitate removal or retention of photosensitive material as part of a lithographic process.

**[0009]** If desired, the holographic image may be made smaller than the original object or lithographic pattern. This may be done by positioning image reduction optics between the H1 master hologram and the photosensitive material. Additionally or alternatively, a second hologram may be formed in a second holographic recording medium by using a coherent light source to illuminate the H1 master hologram to form the holographic image. Light from the holographic image may be used as the object beam. Light that was split off of the coherent light source may be redirected to the second holographic recording medium as a reference beam. Image reduction optics may be positioned between the H1 master hologram and the second holographic recording medium to cause the second hologram to be smaller than the H1 master hologram. The second holographic recording medium may record a hologram that, after processing, defines an "H2 hologram." The H2 hologram may be illuminated to form a smaller holographic image on the photosensitive material.

**[0010]** Through the present invention, nanostructures (for example, structures smaller than 100 nm in dimension, although the scope of the present disclosure should not be limited in this regard) may be successfully formed via the application of a hologram to 3D printing and lithographic processing methods. Diffraction limitations of optical systems may be overcome due to the fact that the holographic image may, itself, be generated through diffraction.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** FIG. **1** is a schematic view of a system for recording a holographic image according to one embodiment of the invention.

**[0012]** FIG. **2** is a flowchart diagram illustrating a method of forming an H1 master hologram according to one embodiment of the invention.

**[0013]** FIG. **3** is a schematic view of a transmission holographic recording system according to one embodiment of the invention.

**[0014]** FIG. **4** is a schematic view of a reflection holographic recording system according to another embodiment of the invention.

**[0015]** FIG. **5** is a schematic view of a Denisyuk holographic recording system according to another embodiment of the invention.

**[0016]** FIG. **6** is a schematic view of a holographic imaging system according to one embodiment of the invention.

**[0017]** FIG. **7** is a flowchart diagram illustrating a method for applying holographic imaging to a fabrication process according to the present invention.

**[0018]** FIG. **8** is a schematic view of a holographic imaging system as applied to 3D printing according to one embodiment of the invention.

**[0019]** FIG. **9** is a schematic view of a holographic imaging system as applied to 3D printing according to another embodiment of the invention.

**[0020]** FIG. **10** is a schematic view of an H2 holographic recording system as applied to 3D printing according to another embodiment of the invention.

**[0021]** FIG. **11** is a schematic view of a holographic imaging system as applied to lithography according to one embodiment of the invention.

**[0022]** FIG. **12** is a schematic view of an H2 holographic recording system as applied to lithography according to another embodiment of the invention.

## DETAILED DESCRIPTION

**[0023]** Various embodiments of the invention will now be described in greater detail in connection with FIGS. **1-12**. The drawings and associated descriptions are merely exemplary; the scope of the invention is defined not by these, but by the appended claims.

**[0024]** Referring to FIG. **1**, a schematic diagram illustrates a system **100** for recording a hologram according to one embodiment of the invention. The system **100** may be designed to record a hologram of an item **110**, which may be a three-dimensional object, a two-dimensional or three-dimensional pattern, or the like. According to certain examples, the item **110** may be an original object that is to be used as a template for producing new objects via 3D printing. According to other examples, the item **110** may be a lithographic pattern that is to be used as a basis for additive or subtractive lithographic processing. In such instances, the item **110** may be an integrated circuit design, an inverse of an integrated circuit design that defines regions between integrated circuit components, or the like. In other embodiments, the item **110** may be used for processes besides 3D printing and lithography, and may be used in other ways than as a manufacturing template.

**[0025]** The system **100** may have a wide variety of configurations, many of which are known in the holography arts. According to the embodiment shown, the system **100** may include a coherent light source **120**, a beam splitter **122**, redirection optics **124**, and a holographic recording medium **126**. Beam expanding optics such as lenses, microscope objectives, and collimating mirrors and optics may be incorporated into system **100** to acquire the needed beam coverage to record the desired hologram.

**[0026]** The coherent light source **120** may be any light source designed to emit coherent light (i.e., light of a substantially uniform wavelength and/or frequency). In this application, "light" is not limited to visible light, but may include electromagnetic radiation of any frequency or wavelength. In certain embodiments, the coherent light source **120** may be a laser or the like. The coherent light source **120** may project a first beam **140** of coherent light toward the beam splitter **122**.

**[0027]** The beam splitter **122** may be designed to receive the first beam **140** and divide the first beam **140** into two components: an object beam **142** and a reference beam **144**. The beam splitter **122** may have any configuration known in the art. If desired, the beam splitter **122** may have the shape of a rectangular prism, which may include two triangular prisms as shown. A portion of the first beam **140** may pass directly through the beam splitter **122** to define the object beam **142**, and the remainder of the first beam **140** may reflect from the interface between the prisms to define the reference beam **144**. The object beam **142** and the reference beam **144** are shown displaced by an angle of 90°, but may be displaced by a variety of different angles in different embodiments. The object beam **142** and/or the reference beam **144** may require the use beam expanding optics such as lenses, microscope objectives and collimating mirrors (not shown). These optics may be incorporated into system **100** to acquire the needed beam coverage to record the desired hologram.

**[0028]** The reference beam **144** may project toward the redirection optics **124**, which may redirect the reference beam **144** toward a holographic recording medium **126**. The holographic recording medium **126** may or may not be applied to a substrate for support. The redirection optics **124** may include various structures that provide the necessary redirection; in certain embodiments, the redirection optics **124** may include one or more mirrors. In addition to or in the alternative to redirection of the reference beam **144**, the object beam **142** may be redirected through the use of redirection optics (not shown).

**[0029]** A portion **146** of the object beam **142** may reflect off of the item **110** toward the holographic recording medium **126**. The portion **146** may cooperate with the reference beam **144** to define an interference pattern at the holographic recording medium **126**. The holographic recording medium **126** may be formed of a material that records this interference pattern to record a hologram **160** of the item **110**.

**[0030]** The holographic recording medium **126** may also be termed a holographic recording film. The holographic recording medium **126** may have any of a variety of compositions known in the art, including but not limited to Silver Halide film, Dichromated gelatin, PMMA, Photosensitive glass, Photosensitive plastic or a variety of photopolymers. The selection of the particular type of holographic recording medium **126** to use may be made based on factors such as the size of the item **110**, the length of the exposure, the required resolution of the hologram **160**, and the like.

**[0031]** The hologram **160** may be a three-dimensional representation of the item **110**. The holographic recording medium **126**, with the hologram **160** recorded thereon, may be subjected to further processing according to the type of holographic medium used to complete creation of the hologram **160**. The hologram **160** may be an H1 master hologram. The H1 master hologram may be used to project a holographic image of the item **110**, which may, without the use of additional optics, occur at a location that duplicates the original spacing between the item **110** and the holographic recording medium **126** when the hologram **160** was made.

**[0032]** Referring to FIG. **2**, a flowchart diagram illustrates a method **200** of forming an H1 master hologram according to one embodiment of the invention. The method **200** may start **210** with a step **220** in which various components are positioned relative to each other in preparation for holographic recording.

**[0033]** The components referenced in the step **220** may include, but are not limited to, the item **110**, the coherent light source **120**, the beam splitter **122**, the redirection optics **124**, and the holographic recording medium **126** of FIG. **1**. These various components may advantageously be positioned in a stable arrangement such as on an optical table that is isolated from vibration or other motion. They may also be positioned in dark environment so that only the desired coherent light impinges against the holographic recording medium **126**.

**[0034]** Once the components have been properly positioned, the method **200** may proceed to a step **230** in which the first beam **140** is projected at the beam splitter **122**, for example, by activating the coherent light source **120**. Then, in a step **240**, the first beam **140** may be divided by the beam splitter **122** into the object beam **142** and the reference beam **144**.

**[0035]** Then, in a step **250**, the object beam **142** may be projected at the item **110**, for example, by the beam splitter **122**, with or without redirection by elements such as the redirection optics **124**. In a step **260**, the reference beam **144** may be projected at the holographic recording medium **126**, for example, by the beam splitter **122**, with or without redirection by elements such as the redirection optics **124**. In a step **270**, a portion of the object beam **142** may reflect from the item **110** toward the holographic recording medium **126**.

**[0036]** In response to impingement of the reference beam **144** and the object beam portion **146** on the holographic recording medium **126**, the hologram **160** may be recorded in a step **280**. Then, in a step **290**, the holographic recording medium **126** with the hologram **160** may be processed further to complete formation of the hologram **160**. This processing may be done according to the type of holographic recording medium used. The hologram **160** may then be an H1 master hologram, which may be used in further holography processes as described above. Then, the method **200** may end **298**.

**[0037]** Referring briefly back to the step **220**, the various components of the system **100** may be positioned in a variety of ways. These may include transmission holography, reflection holography, and Denisyuk holography, which will be shown and described in connection with FIGS. **3**, **4**, and **5**, as follows. Those of skill in the art will recognize that these arrangements are merely exemplary, and other arrangements of the components of the system **100** may be used.

**[0038]** Referring to FIG. **3**, a schematic view illustrates a transmission holographic recording system, or system **300**, according to one embodiment of the invention. The system **300** may be a subset of the system **100** that is uniquely configured for transmission hologram recording. As shown, the reference beam **144** and the portion **146** of the object beam **142** may impinge against the same side of the holographic recording medium **126**. The reference beam **144** may impinge against the holographic recording medium **126** at a desired angle. As in FIG. **1**, the reference beam **144** and the portion **146** of the object beam **142** may cooperate to define an interference pattern, which may cause the hologram **160** to be recorded in the holographic recording medium **126**.

**[0039]** Referring to FIG. **4**, a schematic view illustrates a reflection holographic recording system, or system **400**, according to another embodiment of the invention. The system **400** may be a subset of the system **100** that is uniquely configured for reflection hologram recording. As shown, the reference beam **144** and the portion **146** of the object beam **142** may impinge against different sides of the holographic recording medium **126**. The sides of the holographic recording medium **126** that receive the reference beam **144** and the portion **146** of the object beam **142** may face in directions that are substantially opposite to each other. The reference beam **144** may again impinge against the holographic recording medium **126** at a desired angle. The reference beam **144** and the portion **146** of the object beam **142** may intersect the holographic recording medium **126** and may cooperate to define an interference pattern, which may cause the hologram **160** to be recorded in the holographic recording medium **126**.

**[0040]** Referring to FIG. **5**, a schematic view illustrates a Denisyuk holographic recording system, or system **500**, according to another embodiment of the invention. The system **500** may be a subset of the system **100** that is uniquely configured for Denisyuk hologram recording. As shown, the holographic recording medium **126** may act as a beam splitter. Thus, the beam splitter **122** may be omitted from the system **100**.

**[0041]** The first beam **140** may impinge directly against the holographic recording medium **126** at a desired angle. The holographic recording medium **126** may receive a portion of the first beam **140** as a reference beam, and may allow transmission of the object beam **142** through the holographic recording medium **126** at the item **110**. The portion **146** of the object beam **142** may reflect from the item **110** to the holographic recording medium **126**. The reference beam and the portion **146** of the object beam **142** may intersect the holographic recording medium **126** and may cooperate to define an interference pattern, which may cause the hologram **160** to be recorded in the holographic recording medium **126**.

**[0042]** As set forth above, the hologram **160** may be recorded on the holographic recording medium **126** in a wide variety of ways. After the hologram **160** has been recorded and processed, the resulting H1 master hologram may be used to project holographic images. One way in which this may be accomplished will be shown and described in connection with FIG. **6**.

**[0043]** Referring to FIG. **6**, a schematic view illustrates a transmission holographic imaging system, or system **600**, according to one embodiment of the invention. The system **600** may be used to project a holographic image **610** from the H1 master hologram. The holographic image **610** may resemble the item **110**, and may thus have a shape similar to a shape of the item **110**. The holographic image **610** may not include all of the item **110**; for example, only the portions of the item **110** that were illuminated with coherent light that was reflected to the holographic recording medium **126** (i.e., the portion **146** of the object beam **142**) may be part of the hologram **160**. Thus, the holographic image **610** may include only such portions of the item **110**.

**[0044]** The holographic image **610** may be initiated by projecting a beam **620** of coherent light at the H1 master hologram, i.e., at the H1 hologram **160** recorded on the holographic recording medium **126**. Notably, the beam **620** need not necessarily be coherent light, since no interference pattern is being created. Thus, the light source used to illuminate the hologram **160** may be, but is not required to be, a coherent light source such as a laser. Rather, the coherent light source may instead be a single or narrow line source or even a monochromatic light source that is not coherent.

**[0045]** The beam **620** may be projected at a selected angle, which may be the Bragg angle applicable to the H1 master hologram. This may be the angle at which the reference beam **144** impinged against the holographic recording medium **126** when the hologram **160** was formed. Additionally, the beam **620** may be composed of coherent light with the same wavelength and/or frequency as that originally used to form the hologram **160**. Thus, the coherent light source **120** that was used to form the hologram **160** may advantageously be used to provide the beam **620** of coherent light.

**[0046]** In response to impingement of the beam **620** of coherent light on the hologram**160**, the item **110** may be optically imaged, in space, at the same location, relative to the holographic recording medium **126**, where it was positioned at the time the hologram**160** was formed. This holographic image may be created by diffraction and formed in open space.

**[0047]** The holographic image **610** may be projected at any of a variety of locations. According to the present invention, it may be beneficial to project the holographic image **610** on a photosensitive material. A "photosensitive material" is a material that undergoes a significant change in response to impingement of light. The change that occurs in response to impingement of light may be any of many possibilities, including but not limited to the material becoming solid, gaseous, transparent, opaque, harder, softer, more susceptible to further processing, or less susceptible to further processing. Additionally or alternatively, an index of refraction of the material may change, either upward or downward in response to impingement of the light.

**[0048]** Notably, the change effected by light may not fully be realized without additional processing such as exposure to other substances that, in combination with impingement of the light, enable the full extent of the desired change. Such additional processing may be carried out before, after, or synchronously with Impingement of the light.

**[0049]** FIG. **6** illustrates transmission holographic imaging, which may be, for example, formed via transmission of the beam **620** through the hologram **160** as shown in FIG. **6**. Other holographic imaging methods may be used within the scope of the present invention, including but not limited to reflection holograms. Reflection holograms may be made by projecting a beam, such as the beam **620** of FIG. **6**, at the same side of the H1 master hologram that faces the location of the holographic image. The light may impinge on the hologram **160**, and may then diffract the light in reflection mode to form a holographic image such as the holographic image **610** of FIG. **6**.

**[0050]** FIGS. **8-12** also generally illustrate transmission holographic imaging. In alternative embodiments, the methods carried out in any of FIGS. **8-12** may instead be accomplished through the use of a reflection hologram or other holographic imaging techniques.

**[0051]** Referring to FIG. **7**, a flowchart diagram illustrates a method **700** for applying holographic imaging to a fabrication process according to the present invention. The method **700** is generalized, and thus applies to a wide variety of processes including but not limited to 3D printing and lithography.

**[0052]** The holographic image **610** may be substantially the same size as the item **110**. Alternatively, if desired, the holographic image **610** may be smaller than the item **110**. In the event that the holographic image **610** is to be used for fabrication of nanostructures (for example, via 3D printing or lithography), the holographic image **610** may advantageously be several orders of magnitude smaller than the item **110**.

**[0053]** Thus, the method **700** may include one or more optional image reduction steps; such steps may be omitted if there is no need to reduce the size of the process that occurs relative to that of the original item. Alternatively, in the event that further reduction of the process, relative to the item, is needed, such image reduction steps may be repeated. More specifically, the step **720**, the step **730**, the step **740**, and/or the step **750** may be carried out for image reduction purposes, and may be omitted or repeated as desired. Additionally, the step **780** may also optionally incorporate image reduction.

**[0054]** The method **700** may start **710** with a step **720** in which the components are positioned relative to each other. In this step, the components to be positioned may include the coherent light source **120** (or a different coherent light source), the H1 master hologram, image reduction optics (such as lenses, mirrors, and/or the like), and a second holographic recording medium. These components will be shown and described subsequently in connection with the 3D printing and lithography examples mentioned previously.

**[0055]** As in the step **220**, the step **720** may advantageously include secure fixation of the various components relative to each other in an environment that provides isolation from vibration or other outside motion. Additionally, ambient light may be reduced or eliminated. The coherent light source **120** or other coherent light source may be aimed at the H1 master hologram. If desired, redirection optics such as the redirection optics **124** may be positioned to cause coherent light emitted by the coherent light source **120** or other coherent light source to impinge against the H1 master hologram. The image reduction optics may be positioned between the H1 master hologram and the second holographic recording medium.

**[0056]** The method **700** may then proceed to a step **730** in which the H1 master hologram is illuminated with coherent light. This may entail activation of the coherent light source **120** and/or other coherent light source. In the event that a coherent light source other than the coherent light source **120** used to form the hologram **160** is used, it may beneficially emit coherent light with the same wavelength and/or frequency as that emitted by the coherent light source **120**. The coherent light may impinge against the H1 master hologram.

**[0057]** In responses to impingement of the coherent light against the H1 master hologram, a step **740** may occur, in which a holographic image is projected from the H1 master hologram through the image reduction optics and at the second holographic recording medium. The image reduction optics may be positioned between the H1 master hologram and the second holographic recording medium. Thus, as the holographic image is projected at the second holographic recording medium, it may be reduced in size so that, at the second holographic recording medium, it is much smaller than the item **110**.

**[0058]** In response to projection of the holographic image on the second holographic recording medium, the method **700** may proceed to a step **750** in which the holographic image projected from the H1 master hologram is recorded as a second hologram in the second holographic recording medium. The second hologram may be smaller than the hologram **160** that was originally created from the item **110**. Depending on the reduction power of the reduction optics used, the second hologram may be orders of magnitude smaller than the hologram **160**. After the appropriate processing of the second hologram and the second holographic recording medium in a step **755**, the second hologram may be ready for use as an H2 hologram, as mentioned above.

**[0059]** In the event that the H2 hologram is not sufficiently small, the step **720**, the step **730**, the step **740**, the step **750**, and/or the step **755** may be performed again, substituting the new H2 hologram for the H1 master hologram, and substituting a third holographic recording medium for the second holographic recording medium.

**[0060]** More specifically, the H2 hologram, the image reduction optics, the third holographic recording medium, and the coherent light source **120** (or other coherent light source) may all be positioned relative to each other. The image reduction optics used may be the same as those that were used in the original performance of the step **720**, the step **730**, the step **740**, and the step **750**. Additionally or alternatively, different image reduction optics may be used, and may be positioned between and/or relative to the H2 hologram and the third holographic recording medium.

**[0061]** Then, the H2 hologram may be illuminated with coherent light. A holographic image may be projected from the H2 hologram, through the image reduction optics, and at the third holographic recording medium. A third hologram may be recorded by the holographic image in the third holographic recording medium. The third hologram may be smaller than the second hologram. After the appropriate processing, the hologram recorded in the third holographic recording medium may become an H3 hologram.

**[0062]** In such a manner, the step **720**, the step **730**, the step **740**, the step **750**, and/or the step **755** may be repeated as many times as needed to obtain a holographically recorded image of the desired size. Since each holographic image may be created through diffraction, creation of a reduced holographic image may not be subject to diffraction limitations.

**[0063]** Once a hologram of the desired scale has been created (e.g., in the holographic recording medium **126**, the second holographic recording medium, or a subsequently-used holographic recording medium), the method **700** may proceed to a step **760** in which the components are positioned in preparation for the step **770**, the step **780**, and the step **790**. The components positioned in the step **760** may include the hologram created in the most recent iteration of the step **755** (i.e., an H2 hologram or a subsequently-created hologram, hereinafter "final hologram"), a light source of the required wavelength(s) (such as the coherent light source **120**), the photosensitive material, and/or image reduction optics.

**[0064]** The coherent light source **120** or a non-coherent light source of the required wavelength may be aimed at the final hologram. If desired, redirection optics such as the redirection optics **124** may be positioned to cause coherent light emitted by the coherent light source **120** or a non-coherent light source of the required wavelength to impinge against the hologram. The image reduction optics may be positioned between the final hologram and the photosensitive material. Again, steps may be taken to ensure the stable placement of the components and/or limit the exposure of the components to ambient light.

**[0065]** Once the components have been properly placed, the method **700** may proceed to a step **770** in which a light source of the required wavelength is used to illuminate the final hologram. This may be done, for example, by activating the coherent light source **120** or non-coherent light source of the required wavelength. In the event that the light source used in this step is not the same as the coherent light source that which was used to record the final image, it may beneficially emit light with the same wavelength and/or frequency as that emitted by the coherent light source that was used to record the final hologram. The light may then illuminate the hologram created in the most recent iteration of the step **755**.

**[0066]** In response to impingement of the light against the hologram on which the final image has been recorded, a step **780** may occur, in which a holographic image is projected from the hologram at the photosensitive material. Optionally, this may entail projection of the holographic image through the image reduction optics.

**[0067]** If used in the step **780**, the image reduction optics may be positioned between the final hologram and the photosensitive material. Thus, as the holographic image is projected at the photosensitive material, it may be reduced in size so that, at the photosensitive material, it is smaller than the item **110** and/or the final hologram.

**[0068]** In response to projection of the holographic image on the photosensitive material, the photosensitive material may undergo a significant change. As mentioned previously, this change may take many different forms, and the photosensitive material may require other processing in order for this change to be fully realized. In one example, the photosensitive material may be retained within a reservoir, and may solidify in response to impingement of the holographic image, thus creating a new three-dimensional object. In another example, the photosensitive material may be located on a substrate, and may be made more or less resistant to further etching steps by impingement of the holographic image, thus causing a lithographic pattern to be imaged on the substrate.

**[0069]** Once the holographic image has been projected on the photosensitive material, further processing steps may be performed in a step **790**, depending on the type of fabrication process being carried out. For example, if the process is a 3D printing process, projection of the holographic image into a reservoir of photosensitive material may result in the formation of a new object as the photosensitive material that receives the holographic image solidifies in response.

**[0070]** The step **790** may thus include removal of the new object from the reservoir. If needed, surface treatments such as cleaning, deburring, and/or sanding may be carried out. If the new object includes one or more nanostructures, suitable measures may be taken to locate, protect, and store the nanostructures.

**[0071]** If the process is a lithographic process, projection of the holographic image on photosensitive material on a substrate may cause the photosensitive material that receives the holographic image to solidify. Additionally or alternatively, the photosensitive material that receives the holographic image may become more or less susceptible to subtractive (i.e., material removal) processes such as etching. Thus, holographic imaging may be used to determine which portion of the photosensitive material is preferentially etched away, or may be used to protect material from removal via etching. According to some embodiments, the holographic image may be used to form a mask from the photosensitive material. The mask may serve to protect an underlying material from a material removal process such as etching.

**[0072]** According to alternative embodiments, holographic imaging may be used in combination with additive processes such as sputtering or vacuum deposition. The holographic image may be used to form a mask or selective support layer for such additive processing.

**[0073]** Accordingly, the step **790** may include the performance of a wide variety of steps, including but not limited to subtractive steps such as etching and additive steps such as sputtering or vacuum deposition. Any other steps known in the lithographic arts may be used to continue processing the material supported by the substrate to form an integrated circuit, device, or the like. Again, if one or more nanostructures is formed, suitable steps may be taken to locate, store, and protect the resulting nanostructures. Once the step **790** has been completed, the method **700** may end **798**.

**[0074]** As mentioned previously, holography may be used according to the present invention to facilitate a wide variety of manufacturing processes. FIGS. **8-10** illustrate some potential ways to arrange system components (for example, in the step **720** or the step **760**) to carry out hologram-assisted 3D printing. FIGS. **11** and **12** illustrate some potential ways to arrange system components (for example, in the step **720** or the step **760**) to carry out hologram-assisted lithographic processing.

**[0075]** Referring to FIG. **8**, a schematic view illustrates a holographic imaging system, or system **800**, as applied to 3D printing according to one embodiment of the invention. The system **800** may include the coherent light source **120** or a non-coherent light source of the required wavelength (not shown in FIG. **8**), the hologram, and a reservoir **810** containing photosensitive material **820**. The hologram may be an H1 master hologram, and may thus include the hologram **160** recorded on the holographic recording medium **126**. Alternatively, the hologram may be an H2 hologram, an H3 hologram, or other hologram formed from an H1 master hologram through the use of additional steps as set forth previously. The photosensitive material **820** may be in liquid, gaseous, solid, or amorphous form. In some embodiments, the photosensitive material **820** is in a liquid or gel form and is made to solidify in response to impingement of the light of the holographic image.

**[0076]** FIG. **8** may represent the manner in which the components are arranged in the step **760** if no image reduction is desired. Thus, the reservoir **810** may be positioned, relative to the hologram, such that the holographic image **610** is projected directly (i.e., without reduction) into the photosensitive material **820** within the reservoir **810**. The holographic image **610** may cause a quantity of the photosensitive material **820** to solidify into the shape of the item **110**. The resulting new object may be substantially the same size as the item **110**.

**[0077]** The hologram **160** may be the original hologram recorded directly from the item **110**, as illustrated in FIG. **1**. Thus, the system **800** may represent the arrangement of the components in the step **760** if the step **720**, the step **730**, the step **740**, and the step **750** of the method **700** of FIG. **7** have been omitted, and no further image reduction is desired. In alternative embodiments, the step **720**, the step **730**, the step **740**, and the step **750** may be performed as described in connection with FIG. **7**, and then in the step **760**, the components may be positioned substantially as shown in FIG. **8**, except that in place of the hologram **160** recorded directly from the item **110** (i.e., the H1 master hologram), the hologram with the reduced image (the H2 hologram or another derivative hologram) may be used.

**[0078]** In order to scale the new object relative to the hologram **160** (or alternatively, the already scaled hologram used in place of the H1 master hologram), image reduction optics (or image expansion optics) may be added. One example of this will be shown and described in connection with FIG. **9**.

**[0079]** Referring to FIG. **9**, a schematic view illustrates a holographic imaging system, or system **900**, as applied to 3D printing according to another embodiment of the invention. As shown, the system **900** may be used to provide a holographic image **910** that is scaled relative to the hologram **160**. FIG. **9** may provide image reduction so that the holographic image **910** is relatively smaller than the hologram **160**. This may be achieved by projecting the holographic image **910** through image reduction optics **920**, which may include mirrors, lenses, and/or other features that optically reduce the size of the holographic image **910** relative to that of the hologram **160**.

**[0080]** Depending on the degree of image reduction used, the holographic image **910** may even be one or more orders of magnitude smaller than the item **110** and/or the hologram **160**. If desired, the system **900** may be used to create microstructures and/or nanostructures. Notably, the present invention may be used to create microstructures and/or nanostructures, not just singly, but also in arrays. In the alternative, if desired, the image reduction optics **920** may be replaced with image enlargement optics so that the holographic image **910** is larger than the hologram **160** and/or the item **110**.

**[0081]** If the holographic image **910** is projected from the hologram **160** formed directly from the item **110**, as illustrated in FIG. **9**, the system **900** may represent the arrangement of the components in the step **760** if the step **720**, the step **730**, the step **740**, and the step **750** are omitted. As with the previous embodiment, a hologram such as an H2 hologram or another derivative hologram on which a reduced image of the item **110** has been recorded may be substituted for the H1 master hologram if further reduction is desired.

**[0082]** Referring to FIG. **10**, a schematic view illustrates a holographic imaging system for creating an imaged reduced H2 hologram, or system **1000**, as applied to 3D printing according to another embodiment of the invention. As shown, the system **1000** may also record a hologram that is smaller than the item **110**. However, in FIG. **10**, this may be done by recording a reduced hologram **1060** on a second holographic recording medium **1026**, as in step **720**, step **730**, step **740**, and step **750** of FIG. **7**.

**[0083]** More specifically, image reduction optics **1020** may be positioned between the H1 master hologram and the second holographic recording medium **1026**. The second holographic recording medium **1026** may be positioned at the desired location with respect to where the holographic image **610** would ordinarily be projected relative to the H1 master hologram. Thus, the beam **620** may illuminate the H1 master hologram to cause projection of the holographic image **610** through the image reduction optics **1020**, which may result in recordation of the reduced hologram **1060** on the second holographic recording medium **1026** to provide an H2 hologram.

**[0084]** In order to form the H2 hologram, a reference beam **144** may be projected on the second holographic recording medium **1026**. The holographic image **610** from the H1 master hologram may act as the object beam. The object beam and the reference beam **144** may cooperate to define an interference pattern at the second holographic recording medium **1026**. After processing, the reduced hologram **1060** on the second holographic recording medium **1026** may be used as the H2 hologram.

**[0085]** The H2 hologram may subsequently be used to project a holographic image **1010** smaller than the H1 master hologram. The holographic image **1010** may be used for 3D printing, for example, by positioning the holographic image **1010** within a photosensitive material, such as the reservoir **810** of photosensitive material **820** as in FIG. **8** or FIG. **9**. The holographic image **1010** may be projected into the photosensitive material **820** as shown and described in connection with the holographic image **610** of FIGS. **8** and **9**. The resulting 3D object may be made without further reduction as in FIG. **8**, or with further reduction through the use of image reduction optics **920** as in FIG. **9**.

**[0086]** As mentioned previously, the reduction process embodied in FIG. **10** may not be diffraction limited since the holographic image that forms the hologram **160** may, itself, be formed by diffraction. Thus, a high level of reduction may be obtained with a single iteration. However, if desired, multiple iterations may be performed, for example, by projecting the holographic image **1010** from the H2 hologram through image reduction optics to record a further reduced hologram on a third holographic recording medium (not shown). After processing, this further reduced hologram may be used as an H3 hologram.

**[0087]** The systems and methods of the present invention may offer several advantages, as applied to 3D printing. For example, an entire object may be printed at once and/or made layer by layer. Further, smaller object sizes can be achieved due to the fact that diffraction limitations may not limit the reduction of the holographic image. Yet further, with particular reference to the system **1000** of FIG. **10**, reduction of the holographic image **1010** may be obtained through reduction of the diffracted holographic image as a light source, rather than reduction of the physical image; this may further allow for the formation of smaller objects.

**[0088]** Referring to FIG. **11**, a schematic view illustrates a holographic imaging system, or system **1100**, as applied to lithography according to one embodiment of the invention. The system **1100** may include the coherent light source **120** or a non-coherent light source (not shown in FIG. **11**), the holographic recording medium **126**, and a substrate **1130** on which a layer of photosensitive material **1140** is positioned. The holographic recording medium **126** may have the hologram **160** recorded thereon as an H1 master hologram. In alternative embodiments, the hologram **160** may be an H2 hologram, an H3 hologram, or a subsequent derivative hologram. The photosensitive material **1140** may be in liquid, gaseous, solid, or amorphous form. In some embodiments, the photosensitive material **1140** is in a solid or gel form.

**[0089]** The item **110** used to record the hologram **160** may be a lithographic pattern or the like, and may exist in two or three dimensions. The substrate **1130** and adhering structures may be used to form integrated circuits. If desired, the system **1100** of FIG. **11** may be used to imprint an integrated circuit pattern on the substrate **1130**. Thus, the item **110** used to form the hologram **160** may more specifically be an integrated circuit design, an inverse of an integrated circuit design that defines regions between integrated circuit components, or the like.

**[0090]** FIG. **11** may represent the manner in which the components are arranged in the step **760** of FIG. **7** if image reduction is desired between the holographic recording medium **126** and the photosensitive material **1140**. Thus, the substrate **1130** and the photosensitive material **1140** may be positioned, relative to the H1 master hologram, such that a holographic image **1110** is projected through image reduction optics **1120** onto the photosensitive material **1140**. The image reduction optics **1120** may include mirrors, lenses, and/or other features that optically reduce the size of the holographic image **1110** relative to that of the hologram **160**.

**[0091]** The holographic image **1110** may cause a quantity of the photosensitive material **1140** to become solid, more easily removed, or more resistant to removal as described above. The pattern defined by the holographic image **1110** may match the lithographic pattern of the item **110**. Thus, the holographic image **1110** may define an integrated circuit or the like.

**[0092]** The hologram **160** may be the original hologram recorded directly from the item **110** (i.e., the H1 master hologram), as illustrated in FIG. **1**. Thus, the system **1100** may represent the arrangement of the components in the step **760** if the step **720**, the step **730**, the step **740**, and the step **750** of the method **700** of FIG. **7** have been omitted, and no further image reduction is desired. In alternative embodiments, the step **720**, the step **730**, the step **740**, and the step **750** may be performed as described in connection with FIG. **7**, and then in the step **760**, the components may be positioned substantially as shown in FIG. **8**, except that in place of the holographic recording medium **126** with the hologram **160** recorded directly from the item **110**, the holographic recording medium with the reduced image (the H2 hologram, H3 hologram, or subsequent derivative hologram) may be used.

**[0093]** Depending on the degree of image reduction used, the holographic image **1110** may even be one or more orders of magnitude smaller than the item **110** and/or the hologram **160**. If desired, the system **1100** may be used to create microstructures and/or nanostructures. Notably, the present invention may be used to create microstructures and/or nanostructures, not just singly, but also in arrays. In the alternative, if desired, the image reduction optics **1120** may be replaced with image enlargement optics so that the holographic image **1110** is larger than the hologram **160** and/or the item **110**.

**[0094]** Referring to FIG. **12**, a schematic view illustrates a holographic imaging system for creating an image reduced H2 hologram, or system **1200**, as applied to lithography according to another embodiment of the invention. As shown, the system **1200** may also produce a holographic image **1210** that is smaller than the item **110**. However, in FIG. **12**, this may be done by recording a reduced hologram **1260** on a second holographic recording medium **1226**, as in step **720**, step **730**, step **740**, and step **750** of FIG. **7**.

**[0095]** More specifically, image reduction optics **1220** may be positioned between the H1 master hologram and the second holographic recording medium **1226**. The second holographic recording medium **1226** may be positioned at the location with respect to where the holographic image **610** would ordinarily be projected relative to the H1 master hologram. Thus, the beam **620** may illuminate the H1 master hologram to cause projection of the holographic image **610** through the image reduction optics **1220**, which may result in recordation of the reduced hologram **1260** on the second holographic recording medium **1226** to provide an H2 hologram.

**[0096]** In order to form the H2 hologram, a reference beam **144** may be projected on the second holographic recording medium **1226**. The holographic image **610** from the H1 master hologram may act as the object beam. The object beam and the reference beam **144** may cooperate to define an interference pattern at the second holographic recording medium

**1226**. After processing, the reduced hologram **1260** on the second holographic recording medium **1226** may become the H2 hologram.

**[0097]** The H2 hologram may subsequently be used to project a holographic image **1210** smaller than the H1 master hologram. The holographic image **1210** may be used for lithography, for example, by positioning the holographic image **1210** within a photosensitive material, such as the photosensitive material **1140** on the substrate **1130** as in FIG. **11**. The holographic image **1210** may be projected into the photosensitive material **1140** as shown and described in connection with the holographic image **1110** of FIG. **11**. The resulting lithographic pattern may be made without further reduction, or with further reduction through the use of image reduction optics **1120** as in FIG. **11**.

**[0098]** As mentioned previously, the reduction process embodied in FIG. **12** may not be diffraction limited since the holographic image that forms the reduced hologram **1260** may, itself, be formed by diffraction. Thus, a high level of reduction may be obtained with a single iteration. However, if desired, multiple iterations may be performed, for example, by projecting a holographic image **1210** from the H2 hologram through image reduction optics to record a further reduced hologram on a third holographic recording medium (not shown). After processing, this further reduced image may become an H3 hologram.

**[0099]** The systems and methods of the present invention may offer several advantages, as applied to lithography. For example, an entire wafer may be printed at once, i.e., in a single exposure. Further, smaller object sizes can be achieved due to the fact that diffraction limitations may not limit the reduction of the holographic image. Yet further, with particular reference to the system **1200** of FIG. **12**, reduction of the holographic image **1210** may be obtained through reduction of the diffracted holographic image as a light source, rather than reduction of the physical image; this may further allow for the formation of smaller objects. Hence, small structures such as nanostructures may be lithographically printed. In contrast to known interference lithography techniques, the present invention may permit non-periodic patterns to be lithographically printed.

What is claimed is:

**1**. A contact apparatus for a rapid-charging system for electrically driven vehicles, wherein the contact apparatus serves to form an electrically conductive connection between a vehicle and a stationary charging station having a charging contact, said contact apparatus comprising:

a contact device contactable with the charging contact unit;

a positioning device positioning the contact device relative to the charging contact unit, wherein the positioning device has a pantograph or a swing arm positioning the contact device in the vertical direction relative to the charging contact unit, and;

a contact element support having contact elements, wherein the contact elements contact charging contact elements of the charging contact unit so as to form contact pairs, the positioning device having a transverse guide positioning the contact element support transversely relative to the charging contact unit, wherein the transverse guide is arranged at a distal end of the pantograph or of the swing arm.

**2**. The contact apparatus according to claim **1**, in which the contact device can be arranged on a roof of the vehicle.

**3**. The contact apparatus according to claim **1**, in which the contact elements are arranged on the contact element support relative to the charging contact elements in such a manner that a defined order is maintained when forming contact pairs when the contact device and the charging contact unit are joined.

**4**. The contact apparatus according to claim **1**, in which the contact element support forms at least two positioning surfaces that match contact surfaces of the charging contact unit for coming into contact with the contact element support.

**5**. The contact apparatus according to claim **1**, in which the contact element support is arranged on the transverse guide in a freely displaceable manner.

**6**. The contact apparatus according to claim **1**, in which the contact elements are bolt-shaped and elastically mounted on the contact element support.

**7**. The contact apparatus according to claim **1**, in which at least two contact elements protrude at different heights relative to a surface of the contact element support.

**8**. A charging contact unit for a rapid-charging system for electrically driven vehicles, wherein the charging contact unit serves to form an electrically conductive connection between a vehicle and a stationary charging station, the vehicle having a contact apparatus and the stationary charging station including the charging contact unit, wherein the contact apparatus is arranged on the vehicle and includes a contact device that can make contact with the charging contact unit, wherein the contact apparatus or the charging contact unit includes a positioning device positioning the contact device relative to the charging contact unit, wherein the positioning device has a pantograph or a swing arm positioning the contact device in the vertical direction relative to the charging contact unit, wherein the contact device has a contact element support including contact elements that can make contact with charging contact elements of the charging contact unit so as to form contact pairs, said charging contact unit comprising:

a transverse guide positioning the charging contact unit transversely relative to the contact element support.

**9**. The charging contact unit according to claim **8**, in which the charging contact unit is arranged on the transverse guide in a freely displaceable manner.

**10**. The charging contact unit according to claim **8**, in which the charging contact unit forms a receiving opening for the contact device, wherein the contact device can be inserted into the receiving opening of the charging contact unit.

**11**. The charging contact unit according to claim **10**, in which the receiving opening forms a guide for the contact device when the contact device and the charging contact unit are joined.

**12**. The charging contact unit according to claim **8**, in which the charging contact unit is composed of a charging contact element support and of the charging contact elements, wherein the charging contact element support is made of a plastic material.

**13**. The charging contact unit according to claim **8**, in which the charging contact unit is a roof-shaped longitudinal rail, which can be arranged in a direction of travel of the vehicle.

**14**. The charging contact unit according to claim **8**, in which the charging contact elements are conductor strips.

**15**. A rapid-charging system comprising:

a contact apparatus according to claim **1**; and/or

a charging contact unit having a transverse guide positioning the charging contact unit transversely relative to a contact element support including contact elements that can make contact with charging contact elements of the charging contact unit so as to form contact pairs.

**16**. A method for forming an electrically conductive connection between a vehicle and a stationary charging station for electrically driven vehicles, comprising a contact apparatus and a charging contact unit, wherein the contact apparatus is arranged on a vehicle, wherein the contact apparatus comprises a contact device, said method comprising:

bringing a contact device into contact with a charging contact device of the charging station;

positioning the contact device relative to the charging contact unit using a positioning device having a pantograph or a swing arm positioning the contact device in the vertical direction relative to the charging contact unit;

bringing contact elements of a contact element support into contact with charging contact elements of the charging contact unit so as to form contact pairs; and

positioning the contact element support transversely relative to the charging contact unit using a transverse guide forming part of the positioning device during joining of the contact device and the charging contact unit when bringing the contact elements of the contact element support into contact with the charging contact elements.

**17**. The method according to claim **16**, including forming a first contact pair between a first contact element and a first charging contact element before another contact pair is formed between another contact element and another charging contact element.

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